

How Many Memory Systems Are There?

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ABSTRACT: *Memory is made up of a number of interrelated systems, organized structures of operating components consisting of neural substrates and their behavioral and cognitive correlates. A ternary classificatory scheme of memory is proposed in which procedural, semantic, and episodic memory constitute a "monohierarchical" arrangement: Episodic memory is a specialized subsystem of semantic memory, and semantic memory is a specialized subsystem of procedural memory. The three memory systems differ from one another in a number of ways, including the kind of consciousness that characterizes their operations. The ternary scheme overlaps with dichotomies and trichotomies of memory proposed by others. Evidence for multiple systems is derived from many sources. Illustrative data are provided by experiments in which direct priming effects are found to be both functionally and stochastically independent of recognition memory.*

Solving puzzles in science has much in common with solving puzzles for amusement, but the two differ in important respects. Consider, for instance, the jigsaw puzzle that scientific activity frequently imitates. The everyday version of the puzzle is determinate: It consists of a target picture and jigsaw pieces that, when properly assembled, are guaranteed to match the picture. Scientific puzzles are indeterminate: The number of pieces required to complete a picture is unpredictable; a particular piece may fit many pictures or none; it may fit only one picture, but the picture itself may be unknown; or the hypothetical picture may be imagined, but its component pieces may remain undiscovered.

This article is about a current puzzle in the science of memory. It entails an imaginary picture and a search for pieces that fit it. The picture, or the hypothesis, depicts memory as consisting of a number of systems, each system serving somewhat different purposes and operating according to somewhat different principles. Together they form the marvelous capacity that we call by the single name of *memory*, the capacity that permits organisms to benefit from their past experiences. Such a picture

is at variance with conventional wisdom that holds memory to be essentially a single system, the idea that "memory is memory."

The article consists of three main sections. In the first, I present some pretheoretical reasons for hypothesizing the existence of multiple memory systems and briefly discuss the concept of *memory system*. In the second, I describe a ternary classificatory scheme of memory—consisting of procedural, semantic, and episodic memory—and briefly compare this scheme with those proposed by others. In the third, I discuss the nature and logic of evidence for multiple systems and describe some experiments that have yielded data revealing independent effects of one and the same act of learning, effects seemingly at variance with the idea of a single system. I answer the question posed in the title of the article in the short concluding section.

Pretheoretical Considerations

Why Multiple Memory Systems?

It is possible to identify several a priori reasons why we should break with long tradition (Tulving, 1984a) and entertain thoughts about multiple memory systems. I mention five here.

The first reason in many ways is perhaps the most compelling: No profound generalizations can be made about memory as a whole, but general statements about particular kinds of memory are perfectly possible. Thus, many questionable claims about memory in the literature, claims that give rise to needless and futile arguments, would become noncontroversial if their domain was restricted to parts of memory.

Second, memory, like everything else in our world, has become what it is through a very long evolutionary process. Such a process seldom forms a continuous smooth line, but is characterized by sudden twists, jumps, shifts, and turns. One might expect, therefore, that the brain structures and mechanisms that (together with their behavioral and mental correlates) go to make up memory will also reflect such evolutionary quirks (Oakley, 1983).

The third reason is suggested by comparisons with other psychological functions. Consider, for instance, the interesting phenomenon of *blindsight*: People with damage to the visual cortex are blind in a part of their visual field in that they do not see objects in that part, yet they can accurately point to and discriminate these objects in a forced-choice situation (e.g., Weiskrantz, 1980; Weiskrantz, Warrington, Sanders, & Marshall, 1974). Such facts imply that different brain mechanisms exist for picking up information about the visual environment. Or consider the massive evidence for the existence of two separate cortical pathways involved in vision, one mediating recognition of objects, the other their location in space (e.g., Mishkin, Ungerleider, & Macko, 1983; Ungerleider & Mishkin, 1982). If "seeing" things—something that phenomenal experience tells us is clearly unitary—is subserved by separable neural-cognitive systems, it is possible that learning and remembering, too, appear to be unitary only because of the absence of contrary evidence.

The fourth general reason derives from what I think is an unassailable assumption that most, if not all, of our currently held ideas and theories about mental processes are wrong and that sooner or later in the future they will be replaced with more adequate concepts, concepts that fit nature better (Tulving, 1979). Our task, therefore, should be to hasten the arrival of such a future. Among other things, we should be willing to contemplate the possibility that the "memory-is-memory" view is wrong and look for a better alternative.

The fifth reason lies in a kind of failure of imagination: It is difficult to think how varieties of learning and memory that appear to be so different on inspection can reflect the workings of one and the same underlying set of structures and processes. It is difficult to imagine, for instance, that perceptual-

motor adaptations to distorting lenses and their aftereffects (e.g., Kohler, 1962) are mediated by the same memory system that enables an individual to answer affirmatively when asked whether Abraham Lincoln is dead. It is equally difficult to imagine that the improved ability to make visual acuity judgments, resulting from many sessions of practice without reinforcement or feedback (e.g., Tulving, 1958), has much in common with a person's ability to remember the funeral of a close friend.

If we reflect on the limits of generalizations about memory, think about the twists and turns of evolution, examine possible analogies with other biological and psychological systems, believe that most current ideas we have about the human mind are wrong, and have great difficulty apprehending sameness in different varieties of learning and memory, we might be ready to imagine the possibility that memory consists of a number of interrelated systems. But what exactly do we mean by a *memory system*?

The Concept of System

We could think of a system simply as a set of correlated processes: Processes within a system are more closely related to one another than they are to processes outside the system. Such an abstract and relatively innocuous definition could be used by those students of memory who, for whatever reasons, are reluctant to consider biology when they think about psychology. It would not distort too many claims I will make about memory systems. However, a more concrete conceptualization—one that refers to the correlation of behavior and thought with brain processes and postulates the verifiable, real existence of memory systems (e.g., Tulving, 1984a)—is preferable because it points to stronger tests of such existence.

Memory systems constitute the major subdivisions of the overall organization of the memory complex. They are organized structures of more elementary operating components. An operating component of a system consists of a neural substrate and its behavioral or cognitive correlates. Some components are shared by all systems, others are shared only by some, and still others are unique to individual systems. Different learning and memory situations involve different concatenations of components from one or more systems. The relatedness of such situations in a natural classification scheme of learning and memory varies directly with the extent to which they entail identical components (Tulving, in press).

Although there is no one-to-one correspondence between tasks and systems (e.g., Kinsbourne, 1976; Tulving, in press), they are nonetheless systematically related: A given memory system makes it possible

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for organisms to perform memory tasks that entail operating components unique to that system. This means, among other things, that intervention with the operation of a system—even if it occurs through a single component of the system—affects all those learning and memory performances that depend on that system. The widespread but systematic effects of a single toxin or microorganism, for example (Rozin, 1976), reflect the fact that many specific memory performances are subserved by the affected system.

Different systems have emerged at different stages in the evolution of the species, and they emerge at different stages in the development of individual organisms. Thus, they can be ordered from “lower” to “higher” systems (or from less to more advanced), provided that it is clearly understood that such attributions are meaningful only with respect to comparisons between combinations of systems, on the one hand, and individual systems alone, on the other (Schiller, 1952). When a new memory system with specialized novel capabilities evolves or develops, it enables the organism to increase the number, and the sophistication, of its memory functions. In this sense, the combination of the new system and the older ones is “higher,” or more advanced than the older ones alone. As an analogy, we can think of an airplane with an autopilot as a more advanced or higher system than one without it, but we would not think of the autopilot alone as a higher system than the airplane.

Procedural, Semantic, and Episodic Memories

A Ternary Classification

Let me now switch gears and discuss a classification scheme according to which memory consists of three major systems. I will refer to them as procedural, semantic, and episodic, primarily for the sake of continuity with previous usage, although these are not necessarily the best terms. The three systems constitute what might be called a *monohierarchical* arrangement (cf. Engelien, 1971). The system at the lowest level of the hierarchy, procedural memory, contains semantic memory as its single specialized subsystem, and semantic memory, in turn, contains episodic memory as its single specialized subsystem. In this scheme, each higher system depends on, and is supported by, the lower system or systems, but it possesses unique capabilities not possessed by the lower systems.

Procedural memory enables organisms to retain learned connections between stimuli and responses, including those involving complex stimulus patterns and response chains, and to respond adaptively to the environment. Semantic memory is characterized

by the additional capability of internally representing states of the world that are not perceptually present. It permits the organism to construct mental models of the world (Craik, 1943), models that can be manipulated and operated on covertly, independently of any overt behaviour. Episodic memory affords the additional capability of acquisition and retention of knowledge about personally experienced events and their temporal relations in subjective time and the ability to mentally “travel back” in time.

The monohierarchical relation among the systems means that only procedural memory can operate completely independently of the other systems. This necessarily happens when an organism does not possess either of the two more advanced systems, and it may happen with higher organisms when situations do not call for the use of the other systems. Semantic memory can function independently of episodic memory but not independently of procedural memory. And episodic memory depends on both procedural and semantic memory in its workings, although, as already mentioned, it also possesses its own unique capabilities. The monohierarchical arrangement also implies that certain kinds of double dissociations between learning and memory tasks are precluded (Tulving, in press).

The monohierarchical scheme discussed here represents a revision of the ideas I had expressed about the relations among procedural, semantic, and episodic memory in *Elements of Episodic Memory* (Tulving, 1983). The revised scheme (Tulving, 1984b), anticipated by Lieury (1979), was prompted by the comments of critics such as Kihlstrom (1984), Lachman and Naus (1984), McCauley (1984), Seamon (1984), Tiberghien (1984), and Wolters (1984). It helps to improve the fit between facts and theory, and it does away with some problems of internal consistency of the earlier formulation.

Each system differs in its methods of acquisition, representation, and expression of knowledge. Each also differs in the kind of conscious awareness that characterizes its operations. Let us briefly consider these differences, taking each in turn.

Acquisition in the procedural system requires overt behavioral responding, whereas covert responding—cognitive activity, or “mere observation”—may be sufficient for the other two. We could also say that the characteristic mode of learning is *tuning* in the procedural system, *restructuring* in the semantic system, and *accretion* in the episodic system, along the general lines suggested by Rumelhart and Norman (1978), as long as we keep in mind the implications of the monohierarchical relation among the systems.

The representation of acquired information in the procedural system is prescriptive rather than descriptive: It provides a blueprint for future action

without containing information about the past (Dretske, 1982). It may be conceptualized in terms of the "stage-setting" metaphor of Bransford, McCarrell, Franks, and Nitsch (1977), a metaphor akin to Craik's (1983) suggestion that the consequences of learning may take the form of "subtle alterations of the system" (p. 345). It can also be specified in terms of changing probabilities of specific responses to specific stimuli (Mishkin, Malamut, & Bachevalier, 1984). When we are dealing with procedural memory, I agree with Bransford et al. (1977) and with Craik (1983) that it is inappropriate to talk about discrete "memory traces."

Representations in the semantic system, however, are different from those in the procedural system; they describe the world without prescribing any particular action. Representations in both the semantic and episodic systems are isomorphic with the information they represent (Dretske, 1982). Representations in episodic memory additionally carry information about the relations of represented events to the rememberer's personal identity as it exists in subjective time and space (e.g., Claparede, 1911/1951; Tulving, 1983).

Expression of knowledge (Spear, 1984) also differs in the three systems. Only direct expression is possible in procedural memory; overt responding according to a relatively rigid format determined at the time of learning is obligatory (Hirsh, 1974; Mishkin & Petri, 1984). On the other hand, acquired knowledge in both semantic and episodic memory can be expressed flexibly, in different behavioral forms. Such knowledge may manifest itself, under conditions far removed from those of original learning, in behaviors quite dissimilar to the behavior entailed in such learning. Overt behavior corresponding to actualized knowledge is only an optional form of expression. In episodic memory, the typical mode of "expression" of remembering is recollective experience, based on synergistic ecphory. It occurs when the organism is in the "retrieval mode" (Tulving, 1983) or has a particular "attitude" (Bartlett, 1932).

The three memory systems are characterized by different kinds of consciousness (Tulving, 1985). Procedural memory is associated with anoetic (nonknowing) consciousness, semantic memory with noetic (knowing) consciousness, and episodic memory with autonoetic (self-knowing) consciousness. This arrangement is schematically depicted in Figure 1.

Anoetic (nonknowing) consciousness represents one of the end points of the continuum: It refers to an organism's capability to sense and to react to external and internal stimulation, including complex stimulus patterns. Plants and very simple animals possess anoetic consciousness as do computers and learning machines that have knowledge and that can

improve it (e.g., Hayes-Roth, Klahr, & Mostow, 1980).

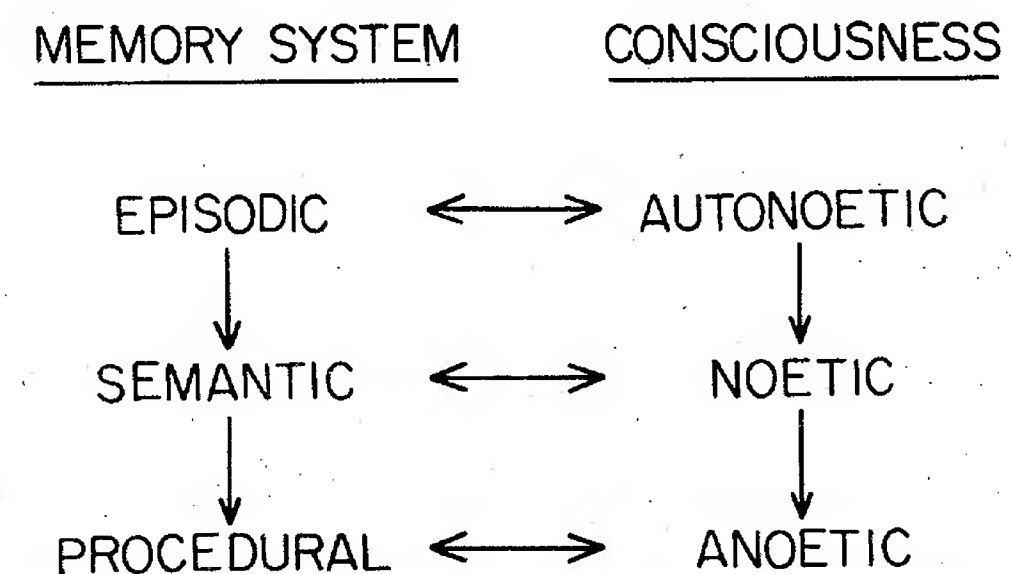
Noetic (knowing) consciousness is an aspect of the semantic memory system. It makes possible introspective awareness of the internal and external world. We can say that the object of noetic consciousness is the organism's knowledge of its world. Noetic consciousness is to such knowledge as the knowledge is to the world. Lower animals, very young children, and people suffering from brain damage may lack episodic memory and autonoetic consciousness but may have fully developed noetic consciousness.

Autonoetic (self-knowing) consciousness is a necessary correlate of episodic memory. It allows an individual to become aware of his or her own identity and existence in subjective time that extends from the past through the present to the future. It provides the familiar phenomenal flavor of recollective experience characterized by "pastness" and subjective veridicality. It can be impaired or lost without impairment or loss of other forms of consciousness.

Other Classificatory Schemes

The ternary classificatory scheme I have described is quite closely related to schemes proposed by other multiple-memory theorists. Although most of these represent various kinds of dichotomies, some tripartite divisions have also been suggested. Ruggiero and Flagg (1976), for instance, have distinguished among "stimulus-response," "representational," and "organized" memory, and a similar scheme has been adopted by Oakley (1981) who referred to the three varieties as "associative," "representational," and "abstract." The first of these categories is analogous to procedural memory in that it involves the learning and retention of stimulus-response connections and

Figure 1
Schematic Arrangement of Three Memory Systems and Three Kinds of Consciousness



Note. An arrow means "implies."

chains; the second is similar to episodic memory in that it represents the capability of forming and storing particular representations of situations and events together with their spatiotemporal context; the third is analogous to semantic memory in that it enables the organism to store context-free facts abstracted from specific instances.

Oakley (1981) has made a systematic attempt to relate the dichotomies suggested by other multiple-system theorists (e.g., Hirsch, 1974; Iversen, 1976; Moore, 1979; O'Keefe & Nadel, 1978; Olton, Becker, & Handelmann, 1979) to his own tripartite scheme. More recent proposals for memory dichotomies include the "knowing how" versus the "knowing that" systems of Cohen and Squire (Cohen, 1984; Cohen & Squire, 1980; Squire & Cohen, 1984), and a similar distinction between the habit system and the "memory" system made by Mishkin and his associates (e.g., Mishkin, Malamut, & Bachevalier, 1984; Mishkin & Petri, 1984). The "knowing how" and habit systems are akin to Oakley's associative memory, the "knowing that" and "memory" systems to Oakley's combined representational and organized memory systems.

Some other recent distinctions are more difficult to compare with either Oakley's (1981) scheme or the ternary scheme discussed in this article. Thus, for instance, Warrington and Weiskrantz's (1982) "semantic" system seems to encompass more than just the associative or the procedural system, and their "cognitive mediational" system transcends the representational or the episodic system. Schacter and Moscovitch's (1984) "early" and "late" systems appear to be analogous to procedural and (undeveloped) semantic systems in the ternary scheme, but this conjecture must await further evaluation.

Some other taxonomic schemes reflect different orientations to the classification problem altogether. Thus, for instance, Pribram's (1984) hierarchical classification of varieties of "cognitive learning" in primates goes considerably beyond simple dichotomies, which he eschewed. In Johnson's (1983) multiple-entry modular memory system the three modules ("subsystems") have no fixed relation to one another but interact variably and continually in different tasks. In her scheme, therefore, no system operates by itself, as the procedural system of the ternary scheme does in some organisms (animals, infants, brain-damaged patients).

On the basis of his review of the literature, Oakley (1981) suggested that the neural substrate of associative memory is subcortical, that representational memory processes depend on both the neocortex and the septo-hippocampal structures, and that abstract memory is subserved by the neocortex. Pribram (1984) also has identified brain structures involved in different kinds of learning. These kinds

of suggestions necessarily remain tentative and uncertain, not only because of the paucity of relevant data but also because of the lack of systematic knowledge of functional composition of the kinds of tasks that have been used in lesion and stimulation experiments. Observation that performance on a task is impaired following some treatment, for instance, does not tell us why it is impaired or which of the many functional components of the task has been affected. Especially problematic in this respect are comparisons and assumed parallels between animal and human learning tasks.

Given the diversity of evidence that different theorists have brought to bear upon the enterprise and the different backgrounds from which they come, we should be more pleased with the overall agreement among theorists than concerned about their differences. Some open problems may be worth mentioning, however.

The first concerns the number of major systems. Just about everyone agrees on the reality of a major division between procedural memory (stimulus-response memory, associative memory) on the one hand and the "other kind" on the other. The currently popular open question has to do with what this "other kind" is and whether it is one or two. Many investigators say "one." Different versions corresponding to the "one" position have been promulgated or approvingly mentioned, among others, by Anderson and Ross (1980), Baddeley (1984), Craik (1983, in press), Hintzman (1984), Jacoby (1983a, 1983b), Kihlstrom (1984), Klatzky (1984), Lachman and Naus (1984), McCloskey and Santee (1981), McKoon and Ratcliff (1979), Moscovitch (1982), and Roediger (1984). Some others say "two" (e.g., Herrmann, 1982; Herrmann & Harwood, 1980; Kinsbourne & Wood, 1975, 1982; Oakley, 1981; O'Keefe & Nadel, 1978; Olton, 1984; Ruggiero & Flagg, 1976; Shoben, Wescourt, & Smith, 1978; Warrington, 1981; Wood, Ebert, & Kinsbourne, 1982; Wood, Taylor, Penny, & Stump, 1980). A large majority of the students of learning and memory have yet to join the debate on either side.

A second problem has to do with the identity of the two nonprocedural systems and the nature of the relation between them. It is not immediately clear how we can evaluate suggestions such as those made by Ruggiero and Flagg (1976), as well as Oakley (1981), that representational memory in animals corresponds to episodic memory in humans, or the suggestion of Olton (1984) that animals have episodic memory, too. The ideas make good sense: The ability to register, store, and make use of information concerning past events does characterize episodic memory just as it characterizes abstract memory. On the other hand, it is unclear whether animals possess the capability of recollecting past

events as being a "part of" their own past in the same way as people do. There is mounting evidence that brain-damaged patients who have lost their ability to recollect specific episodes and to acquire new ones, and who do not have what I have called autonoetic consciousness, nonetheless can not only use previously learned semantic knowledge (e.g., Cermak & O'Connor, 1983) but can also extract new semantic knowledge from learning episodes (e.g., Glisky, Schacter, & Tulving, 1984; Schacter, Harbluk, & McLachlan, 1984). This fact suggests that animals, too, might be capable of acquiring information about aspects of past events even if they do not possess any system similar to the episodic system in humans. Thus, the distinction between representational and abstract memory in animals (Oakley, 1981) need not quite correspond to the one between episodic and semantic memory in humans. Of course, as long as we think of episodic memory in humans as being merely *analogous* to forms of animal memory, such as Olton's working memory (Olton, 1984, in press), and do not insist on the two being identical, or even homologous, we are probably on firm ground.

A third problem has to do with the order of development of the two nonprocedural systems. I agree with Kinsbourne and Wood (1975), and I think that in both phylogenetic and ontogenetic development, the semantic system precedes the episodic one. Others (e.g., Lachman & Naus, 1984; Seamon, 1984) believe that the order is reversed. The classificatory schemes of Ruggiero and Flagg (1976) and Oakley (1981) imply the developmental priority of representational (analogous to episodic) memory, in agreement with Lachman and Naus and with Seamon. The matter clearly needs attention, thought, and clarification. (See Schacter & Moscovitch, 1984, for a discussion.)

Nature and Logic of Evidence

Evidence for Memory Systems

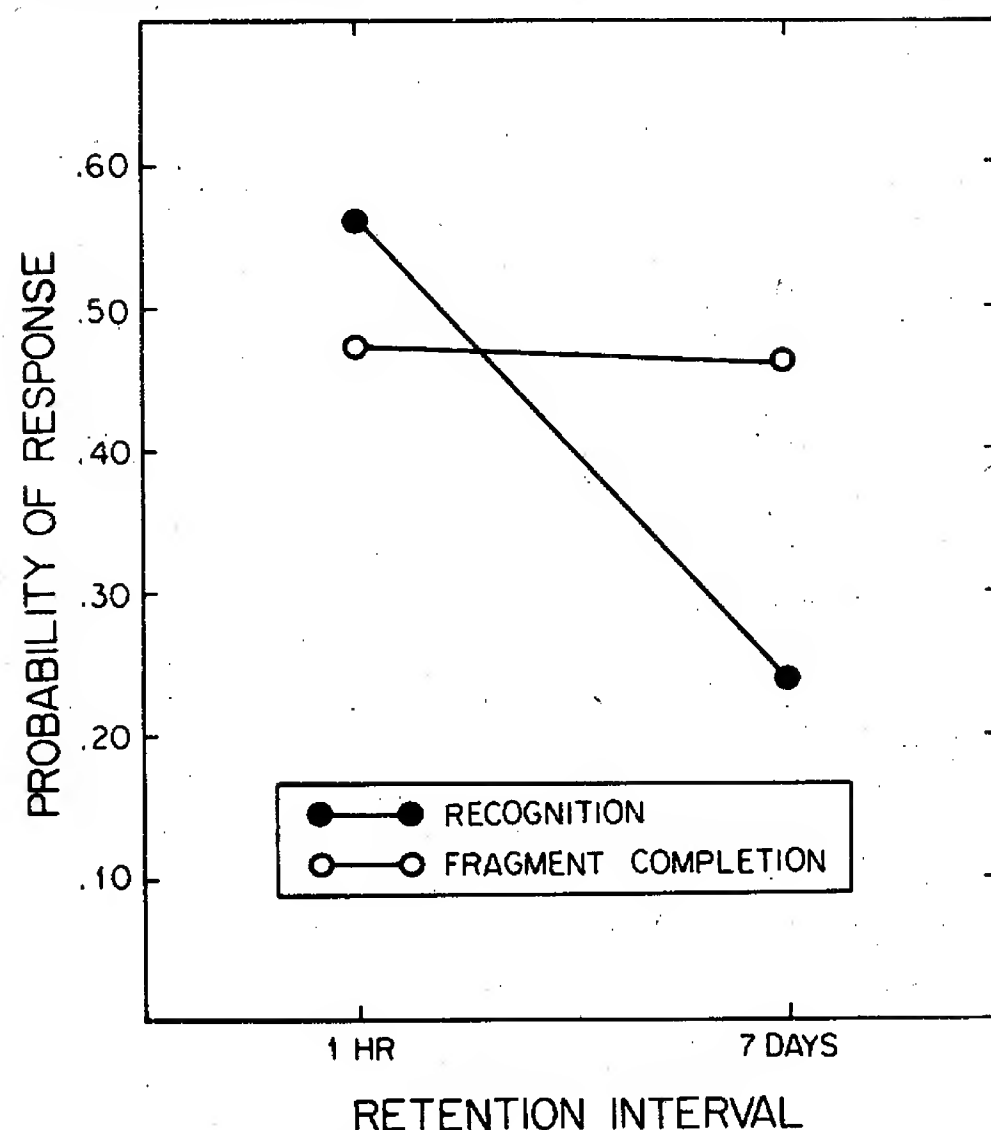
Evidence for classificatory schemes of memory such as those proposed by Ruggiero and Flagg (1976) and Oakley (1981) is derived from experiments in which the effects of brain lesions or brain stimulation (Olton, in press) are observed on the performance of two or more learning or memory tasks. The basic form of findings relevant to making distinctions among memory systems is one in which a particular lesion or a particular type of stimulation affects the performance on one task but not on the other. We can refer to such a finding as demonstrating a functional dissociation of tasks. Many such findings reported in the literature have been reviewed by Hirsh (1974), O'Keefe and Nadel (1978), and by Oakley (1981, 1983).

The ternary classification I have described here is supported by two different sets of evidence. One has to do with the distinction between procedural and propositional memory; such evidence has been reviewed by Baddeley (1984), Moscovitch (1982), and Squire and Cohen (1984), among others. The second type of evidence concerns the episodic/semantic distinction, and its various aspects have been discussed and reviewed by Kinsbourne and Wood (1975, 1982), Parkin (1982), Rozin (1976), Schacter and Tulving (1982), Tulving (1983, 1984b), and Wood, Ebert, and Kinsbourne (1982), among others. I will make no attempt to summarize this evidence here. Instead, I will discuss and analyze a particular kind of experiment, yielding a particular kind of result, that appears as one of the more interesting and promising pieces of the puzzle.

The experiment is one in which people are shown familiar words and are then given two different "memory" tests on the studied, as well as unstudied, words. In one test, recognition memory, they have to remember whether they saw the test word in the study list. Performance on this test can be assumed to depend on, or at least to be greatly facilitated by, the episodic system. In the other, a word fragment completion test, people have to "think of" a word that matches a graphemic fragment. Thus, for instance, if the fragment is o_hur, they have to come up with the word *yoghurt*; if the fragment is e_d_l_m, they have to complete it as *pendulum*. Although people can complete a certain percentage of word fragments on the basis of their general knowledge of words, prior presentation of the words in the study list enhances their completion performance.

Inspired by the classic studies of Warrington and Weiskrantz (1970, 1974), we did an experiment in which we compared recognition memory and fragment completion (Tulving, Schacter, & Stark, 1982). Although we found a sizable reduction in recognition over a seven-day interval, we found very little such forgetting in fragment completion. The relevant data are summarized in Figure 2. The data mimic other similar patterns of functional dissociation between tasks (for example, see Jacoby & Dallas, 1981; Kihlstrom, 1980; Shoben, Wescourt, & Smith, 1978). But an even more interesting factor yielded by our experiment was that levels of performance on the two tasks of word recognition and fragment completion were not correlated at all. It is this lack of correlation, or stochastic independence, between recognition and fragment completion that greatly encourages thoughts about different memory systems. To place the finding into proper perspective and to appreciate its implications, however, we should first consider a simple, well-known fact about memory.

Figure 2
Recognition Memory and Primed Fragment Completion Performance as a Function of Retention Interval



Note. Recognition memory = hit rate minus false alarm rate. Data are from "Priming Effects in Word-Fragment Completion Are Independent of Recognition Memory" by E. Tulving, D. L. Schacter, and H. Stark, 1982, *Journal of Experimental Psychology: Human Learning and Memory*, 8, pp. 336-342. Copyright 1982 by the American Psychological Association.

Contingency Analyses of Measures of Memory

The well-known fact comes from list-item experiments in which a person studies a list of familiar words and is then given two different tests, a recognition test and a recall test. All such experiments show that recognition is easier than recall. They also show that there is a good positive correlation between recognition and recall when individual items are taken as units of analysis: The probability of recall is greater for items that can be recognized than for those that cannot. (For an interesting exception, see Broadbent & Broadbent, 1975, the discussion by Rabinowitz, Mandler, & Patterson, 1977, and the rebuttal by Broadbent & Broadbent, 1977.)

Let us look at data from a particular version of this kind of an experiment (Ogilvie, Tulving, Paskowitz, & Jones, 1980). University students studied a list of familiar words, shown one at a time, for three seconds each. They were then given two tests: first a standard yes/no recognition test, and second a cued-recall test with extralist cues, either associatively related to, or rhyming with, target words.

The results of the experiment, for both associative cues and rhyming cues, are summarized in Table 1. In both cases, the data are tabulated in a contingency table that represents four possible outcomes: (a) target word both recognized and recalled, (b) target word recognized but not recalled, (c) target word not recognized but recalled, or (d) target word neither recognized nor recalled.

The fact we should note about these two sets of data is the positive correlation, or association, between recall and recognition: The proportion of recalled words that are also recognized (shown at the bottom of Table 1) is greater than the proportion of all test words recognized. The fact that recognition thus conditionalized on recall is higher than overall recognition means that the two measures, recall and recognition, are positively correlated, or dependent, in this contingency analysis.

Now we are ready to consider what happens when we make what appears to be a minor change in the procedure. The change is that we use word fragments as cues in the recall test. Otherwise the procedure is the same: presentation of familiar words for study, one at a time, followed first by a recognition test and then by a fragment completion test (Tulving, Schacter, & Stark, 1982). Because we know that graphemic word fragments are very effective cues for recall (see, for example, the experiment described by Tulving, 1976, pp. 52-53), we might expect that the relation between recognition and fragment completion in this new experiment would

Table 1
Results of the Ogilvie et al. (1980) Experiment: Probability of Recall With Associative and Rhyming Cues

| Recognition | Recall | | Total |
|------------------|--------|-----|-------|
| | 1 | 0 | |
| Associative cues | | | |
| 1 | .47 | .20 | .67 |
| 0 | .05 | .28 | .33 |
| Total | .52 | .48 | |
| Rhyming cues | | | |
| 1 | .20 | .50 | .70 |
| 0 | .02 | .28 | .30 |
| Total | .22 | .78 | |

Note. The conditional probability of recognition given recall, $P(R_n|R_c)$, is .90 for associative cues and .91 for rhyming cues. Data are from the experiment described in "Three-Dimensional Memory Traces: A Model and Its Application to Forgetting" by J. C. Ogilvie, E. Tulving, S. Paskowitz, and G. V. Jones, 1980, *Journal of Verbal Learning and Verbal Behavior*, 19, 405-415. Copyright 1980 by Academic Press, Inc.

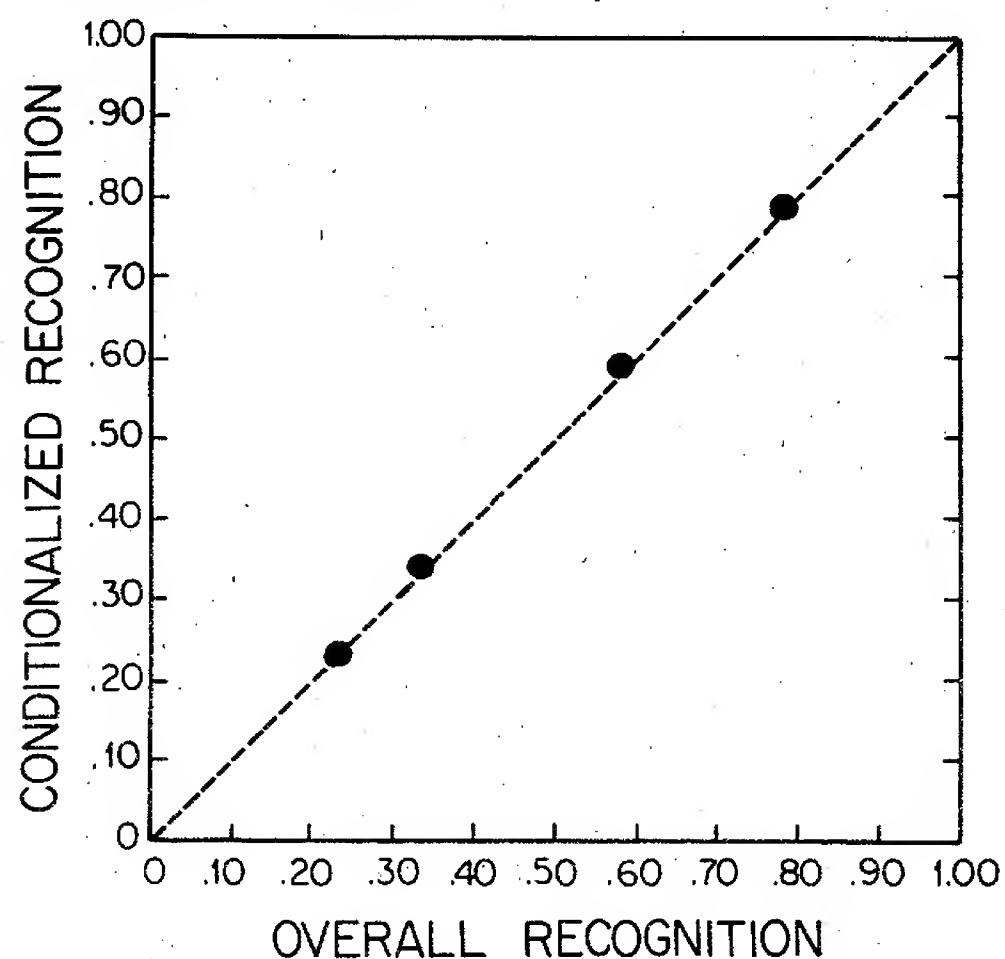
be similar to that between recognition and cued recall, namely one of dependence. But it is not. More often than not, the relation is one of stochastic independence.

Stochastic Independence

The data from the Tulving et al. (1982) experiment are summarized in Figure 3 in the form of a graph in which recognition conditionalized on fragment completion is plotted against overall recognition. Figure 3 shows that in four different conditions of the experiment—study list words and recognition test lures tested after one hour and after one week—conditionalized recognition did not differ from overall recognition. Such a state of affairs means that recognition and fragment completion in this experiment were completely uncorrelated, or stochastically independent of one another.

This is a remarkable result: A word's appearance in the study list enhances the subject's ability to generate the word to its fragment cue, but such enhancement is identical for the remembered words and for those not remembered. Thus, we have here two manifestations of one and the same single act of learning, one measured by recognition, the other by the enhanced ability to complete fragments, and the two seem to have nothing in common. Note

Figure 3
Probability of Recognition Conditionalized on Fragment Completion as a Function of Overall Recognition Hit Rate



Note. Data are from "Priming Effects in Word-Fragment Completion Are Independent of Recognition Memory" by E. Tulving, D. L. Schacter, and H. Stark, 1982, *Journal of Experimental Psychology: Human Learning and Memory*, 8, pp. 336-342. Copyright 1982 by the American Psychological Association.

that the positive dependence between recognition and cued recall observed in the Ogilvie et al. (1980) experiment and in many other similar studies (e.g., Rabinowitz et al., 1977) rules out the possibility that the stochastic independence is simply an artifact of the method of successive testing or of the contingency analysis.

The finding of stochastic independence between recognition and fragment completion has been replicated by Light, Singh, and Capps (1984) with both young and older subjects and in our own laboratory with both normal subjects (e.g., Chandler, 1983) and with amnesic patients (Schacter, McLachlan, Moscovitch, & Tulving, 1984). Similar findings of stochastic independence between measures of memory have been reported by Jacoby and Witherspoon (1982) who compared recognition memory with tachistoscopic identification of study list words under conditions where tachistoscopic identification, like fragment completion, shows benefits of earlier exposure in the study list.

Let us consider the experiment done by Chandler (1983). Her design was patterned after that of the Tulving et al. (1982) experiment, but it comprised many more conditions. Subjects studied either short (12 words) or long (48 words) lists and were then tested in two sessions, one immediately after study, the other 24 hours later, under two sets of recall instructions, one emphasizing the correspondence between test fragments and study list words, the other leaving this connection unspecified. The design of Chandler's experiment made it possible to examine the correlation between recognition and recall in 32 separate conditions, 16 entailing words seen on the study list, and the other 16 entailing words not seen in the experiment before the recognition test. Chandler's data are shown in Figure 4. The outcome is uniform: Conditionalized recognition is essentially identical with simple recognition, that is, recognition and fragment completion are stochastically independent.

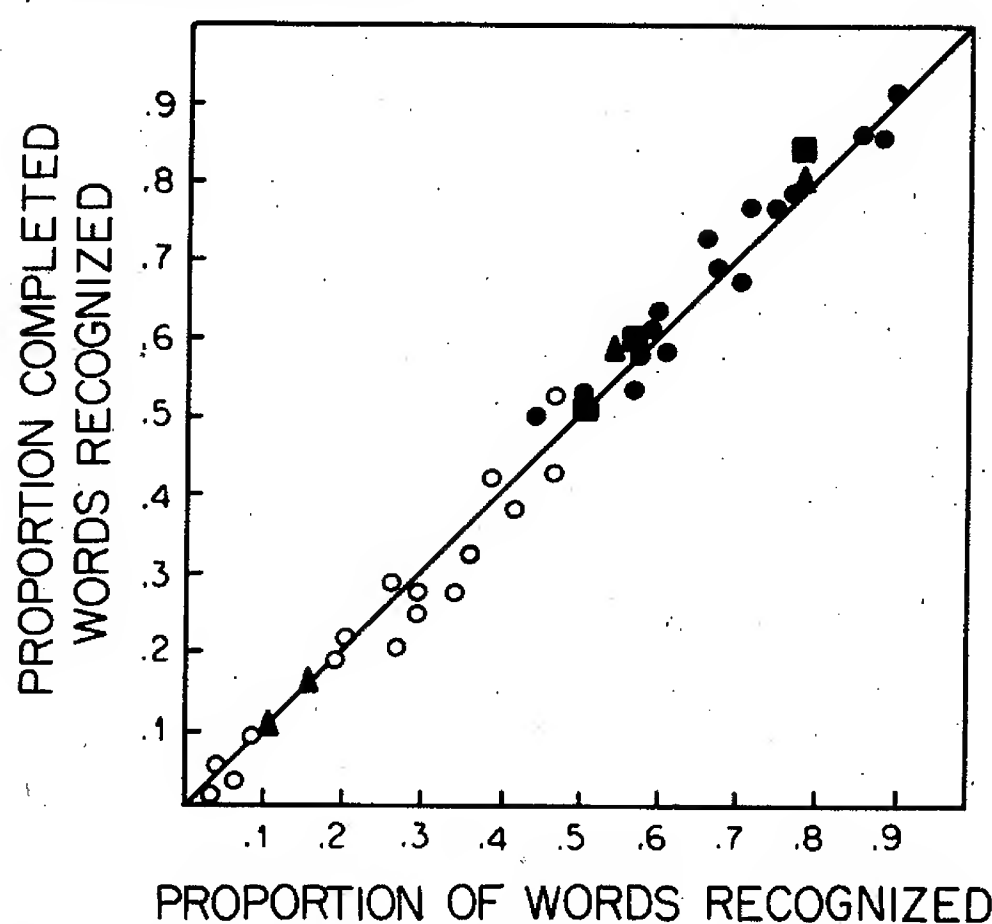
In other work in our laboratory, we have obtained results showing stochastic independence between recognition and two other tasks that do not require remembering of a particular learning episode but that do reveal the effects of learning of the kind that manifests itself in enhanced fragment completion or tachistoscopic identification, learning that is named *direct priming*, or simply *priming*. One of these is the anagram-solution task. People are given scrambled letters of a word, such as *tineki* and *hubels*, and they have to rearrange the letters to make a word, such as *kitten* and *bushel*. It is known that anagram solutions show priming effects derived from earlier exposure to the target words (e.g., Dominowski & Ekstrand, 1967; Jablonski & Mueller, 1972).

In one experiment, patterned after Tulving et al. (1982), but using anagram solutions instead of fragment completion, Harriet Mable tested subjects in two test sessions, one on the day of study, the other 24 hours later. Her results, for study-list words

and recognition-test lures, and from the same-day test and a test given 24 hours later, are indicated by the four filled triangles in Figure 4.

The other task is what we call the shadow face identification task. At the time of the study, subjects are shown shadow faces of the kind depicted in Figure 5, and then 24 hours later, they are tested for recognition of these faces and for their ability to "perceive" faces on the basis of fragments of the faces of the kind shown in Figure 6. Note that the question put to the subjects here, as in fragment completion and anagram solutions, is not whether they saw the face before, but whether they can "see" the face, to construct it in their own minds, on the basis of fragmentary cues. The faces, inspired by Mooney (1956), were drawn by Anne Ellis. Ellis also carried out three preliminary experiments with these materials. Results from these three experiments with the face-identification task are indicated by the three filled squares in Figure 4.

Figure 4
Probability of Recognition Conditionalized on Fragment Completion, Anagram Solution, and Face Identification as a Function of Overall Recognition Hit Rate



Note. Fragment completion data are shown in circles. Data are from "Does Retrieval Strategy Determine the Relation Between Episodic Recognition and Semantic Priming?" by C. Chandler, 1983, unpublished master's thesis, University of Toronto, Toronto, Canada. Used by permission of the author. Anagram solution data are shown in squares and are based on work done by H. Mable in E. Tulving's laboratory, University of Toronto, Toronto, Canada. Face identification data are shown in triangles and are based on work by A. Ellis in E. Tulving's laboratory.

Independence Is Not Independence

Stochastic independence between a measure of learning that requires remembering particular episodes (recognition) and measures that do not require it ("primed" fragment completion, tachistoscopic identification, anagram solutions, and identification of faces) seems to represent a reliable phenomenon. What does it mean, and how does it fit into the picture of multiple memory systems?

To answer these questions, it is first necessary to distinguish between *stochastic independence* and what has been called *functional independence*. Stochastic independence is the name given to the relation between two events in which the probability of their joint occurrence is equal to the product of the probabilities of the occurrence of each event alone.

Figure 5
Examples of Shadow Faces Used in the Ellis Experiments



Figure 6
Fragmented Shadow Faces Corresponding to Those Shown in Figure 5



It is based on subject items as units of analysis, and its occurrence requires no systematic manipulation of any independent variables. Functional independence, on the other hand, refers to the relation between two dependent variables in a situation in which one variable does and the other one does not vary as a *function* of an independent variable. Functional independence could also be called functional dissociation, or cross-over interaction (see Loftus, 1978).

It is important to realize that there is no necessary logical connection between these two kinds of independence. We could say that "independence is not independence"; it all depends on how relations are specified. It is perfectly possible to find one kind of independence in a particular situation and not the other. Because this simple fact does not seem to be widely known but is important, it may be worth emphasis and a concrete illustration.

Table 2
A Set of Imaginary Data From an Experiment in Which Three Subjects Are Tested With Three Items on Each of Two Tests, X and Y

| Subjects | Items | | | Sum |
|----------|-------|------|------|------|
| | 1 | 2 | 3 | |
| A | 1, 1 | 1, 1 | 1, 1 | 3, 3 |
| B | 1, 0 | 1, 1 | 0, 1 | 2, 2 |
| C | 1, 0 | 0, 0 | 0, 1 | 1, 1 |
| Sum | 3, 1 | 2, 2 | 1, 3 | |

Note. The first entry in each pair is the score on Test X, and the second entry is the score on Test Y.

Consider an imaginary set of data shown in Table 2. Each of three subjects, A, B, and C, is tested for the knowledge of each of three items, 1, 2, and 3, in two tests, X and Y. Each subject either succeeds (receiving a score of 1), or fails (receiving a score of 0), with respect to a given item on a given test. The data in Table 2 can be arranged to show that the two tests, X and Y (or two dependent variables), are (a) perfectly positively correlated, (b) perfectly negatively correlated, and (c) perfectly uncorrelated, all at the same time. Thus, if we take subjects as the units of analysis (for each subject, the data are pooled over all three items), X and Y are perfectly positively correlated ($r = 1.0$), but if we take items as the units (each item is given a score on each test, with the data pooled over all subjects), X and Y are perfectly negatively correlated ($r = -1.0$). The fact that one and the same set of data can show positive and negative correlations simultaneously has been previously pointed out and discussed by Mandler (1959). Here we note the additional point that a given set of data can show zero correlation simultaneously with positive and

Table 3
Data from Table 2 Rearranged in the Form of a Contingency Table

| Test X | Test Y | | Total |
|--------|--------|---|-------|
| | 1 | 0 | |
| 1 | 4 | 2 | 6 |
| 0 | 2 | 1 | 3 |
| Total | 6 | 3 | |

negative correlations between the same dependent variables. Thus, when we rearrange the data in Table 2 into a fourfold contingency table, as shown in Table 3, it turns out that the two measures, X and Y, are completely independent stochastically.

The independence of functional and stochastic independence has two important implications for the pursuit of our puzzle. One, explanations constructed to account for functional independence may leave stochastic independence unexplained. Two, findings of stochastic independence are much more relevant to the classification problem than findings of functional independence, because they impose tighter constraints on theory.

Functional independence has been demonstrated in many experiments. Much of the evidence in support of multiple memory systems of the kind discussed by Oakley (1981) takes the form of functional dissociations, and so do results that have been used to support the distinction between procedural and propositional memory (e.g., Cohen & Squire, 1980). I used experiments demonstrating functional independence in arguing for the distinction between episodic and semantic memory systems (Tulving, 1983).

Although functional dissociations can be interpreted as supporting ideas concerning multiple memory systems, the evidence they provide is not compelling. It is perfectly possible to interpret data showing functional independence without any need to postulate different systems (Roediger, 1984). For example, one of the more thoroughly investigated functional dissociations—that between recognition and free recall (Anderson & Bower, 1972; Kintsch, 1970; McCormack, 1972; Tulving, 1976)—can be readily interpreted within the generation-recognition model (Watkins & Gardiner, 1979). This model assumes that one of two stages of processing in recall is absent in recognition and that the other stage is common to the retrieval tasks. The discrepant stage is responsible for the functional independence between recognition and recall, whereas the common stage underlies the positive correlation or dependence of the two measures.

Evidence provided by stochastic independence is somewhat more compelling: Stochastic independence cannot be explained by assuming that the two comparison tasks differ in only one or a few operating components (information, stages, processes, mechanisms). As long as there is any overlap in those operating components that are responsible for differences in what is retrieved, some positive dependence between the measures should appear. Perfect stochastic independence implies complete absence of such overlap.

Although more compelling, observations of stochastic independence alone will not settle the ques-

tion of the reality of memory systems. Much more converging evidence is necessary, and some of it already exists. Thus, we know that priming effects show much slower forgetting than, say, recognition (e.g., Tulving et al., 1982), that cross-modality transfer is smaller in fragment completion than in recognition (e.g., Ellis & Collins, 1983), that amnesic patients who have great difficulty with recall and recognition show near-normal priming effects (e.g., Graf & Schacter, in press), and that alcoholic intoxication impairs recognition memory but not priming effects in fragment completion (e.g., Parker, Schoenberg, Schwartz, & Tulving, 1983). Additional evidence will most likely be obtained by students of memory working under the banners of neuropsychology, comparative psychology, developmental psychology, cognitive psychology, and other disciplines concerned with plasticity of experience and behavior (Oakley, 1983; Olton, in press; Tulving, in press).

The results I have described here only suggest that the kind of learning reflected in fragment completion and other similar tasks is subserved by a system other than episodic memory. They alone do not tell us what this other system is. We could speculate that fragment completion is basically a procedural memory task, or basically a semantic memory task, but such conclusions are purely conjectural. At the present stage of our knowledge, it is no less plausible to entertain the hypothesis that fragment completion reflects the operation of some other, as yet unknown, memory system, perhaps a precursor to episodic memory. We could refer to this unknown system as the QM system (QM for question mark) and keep our eyes and minds open for evidence for and against its hypothesized existence.

How Many Systems?

The puzzle of memory systems is not and will not be an easy one to solve. Many difficulties have to be overcome before we can expect more rapid progress. We assume that both memory systems and memory tasks (performances, manifestations, achievements) are composed of, or can be broken down into, more elementary constituents (I have referred to them in this article as operating components), but we do not yet know how to relate one to the other in the world of empirical observations. In the absence of such rules of the game, interpretation of existing evidence from the point of view of multiple memory systems is uncertain and frustrating. The difficulty is compounded by the clever and inventive strategies that learners and rememberers frequently use when confronted with laboratory tasks, strategies that drive wedges between what the experimenter thinks he or she is observing and what

the observed organism is in fact doing. A familiar bane of learning and memory researchers is the omnipresent possibility that identical behaviors and responses are produced by different underlying processes and mechanisms. Sometimes crucial theoretical distinctions may depend on fine differences in observed patterns of data, requiring discriminations beyond the resolving power of conventional methodology.

How then, with few facts yet available to guide us and many intractable problems to dampen our enthusiasm, can we expect to answer the question posed in the title of this article? We follow the same procedure that we use when we tackle other puzzles in our science: We exercise our imagination, trying to see beyond the visible horizon, reaching beyond what is given. As long as our imagination is eventually bridled and disciplined by nature's facts, we need not worry about thinking thoughts that transcend our knowledge.

Because I have discussed three systems in this article, in agreement with a number of other friends of multiple learning and memory systems, the answer "three" to our main question would not be entirely amiss at the present time. But if we try to imagine what might lie beyond our currently limited horizon we may decide that a better answer might be "at least three and probably many more."

Whether this or some other answer will prove to come closest to "carving nature at its joints" is something that only the future will show. What matters for the present is that the question is being asked by an increasing number of students of memory. There is no guarantee, of course, that just by asking the question we will get an answer that is acceptable to science. What is absolutely guaranteed, however, is that we will not get the answer unless we pose the question. We cannot solve puzzles that do not exist.

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